CS698T
Wireless Networks: Principles and Practice

Topic 09
Embedded Wireless Sensors: Application Case Studies

Bhaskaran Raman,
Department of CSE, IIT Kanpur

http://www.cse.iitk.ac.in/users/braman/courses/wless-spring2007/

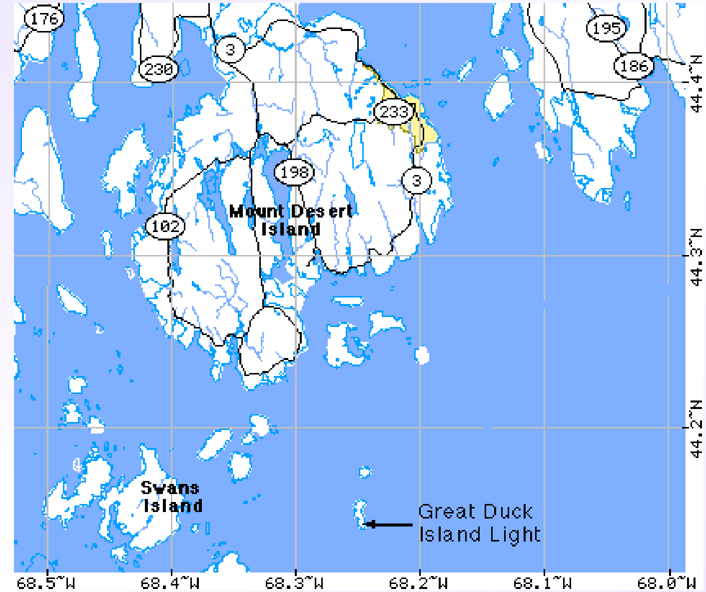
A Detailed Study of a Sensor Network Application

- Reference: "Wireless Sensor Networks for Habitat Monitoring", A. Mainwaring, J. Polastre, R. Szewczyk, D. Culler, J. Anderson, WSNA (Wireless Sensor Networks and Applications), Sep 2002
- Monitoring seabird nesting environment (Leach's Storm Petrel)

Picture: Courtesy Google

Great Duck Island, Maine

Pictures: Courtesy Google



Habitat Monitoring and Sensor Networks

- Impacts of human presence on plants and animals
- Minimal disturbance is crucial while monitoring
  - Especially seabird colonies
  - 20% mortality of eggs due to a 15-min visit
  - Repeated disturbance ==> birds may abandon
  - Leach's storm petrels desert nesting burrows if disturbed in first 2 weeks of incubation
- Natural answer: sensor networks

Motivation: Life Scientists' Perspective

- Usage pattern of nesting burrows over the 24-72 hour cycle when one or both members of a breeding pair alternate incubation and feeding at sea
- Changes in burrow and surface environmental parameters during the 7-month breeding season
- Differences in micro-environments with and without large numbers of nesting petrels

Motivation: Sensor Networks Perspective

- Application-driven approach better than abstract problem statements
  - Separate actual problems from potential ones
  - Relevant versus irrelevant issues
- Develop an effective sensor network architecture
  - Learn general solutions from specific ones

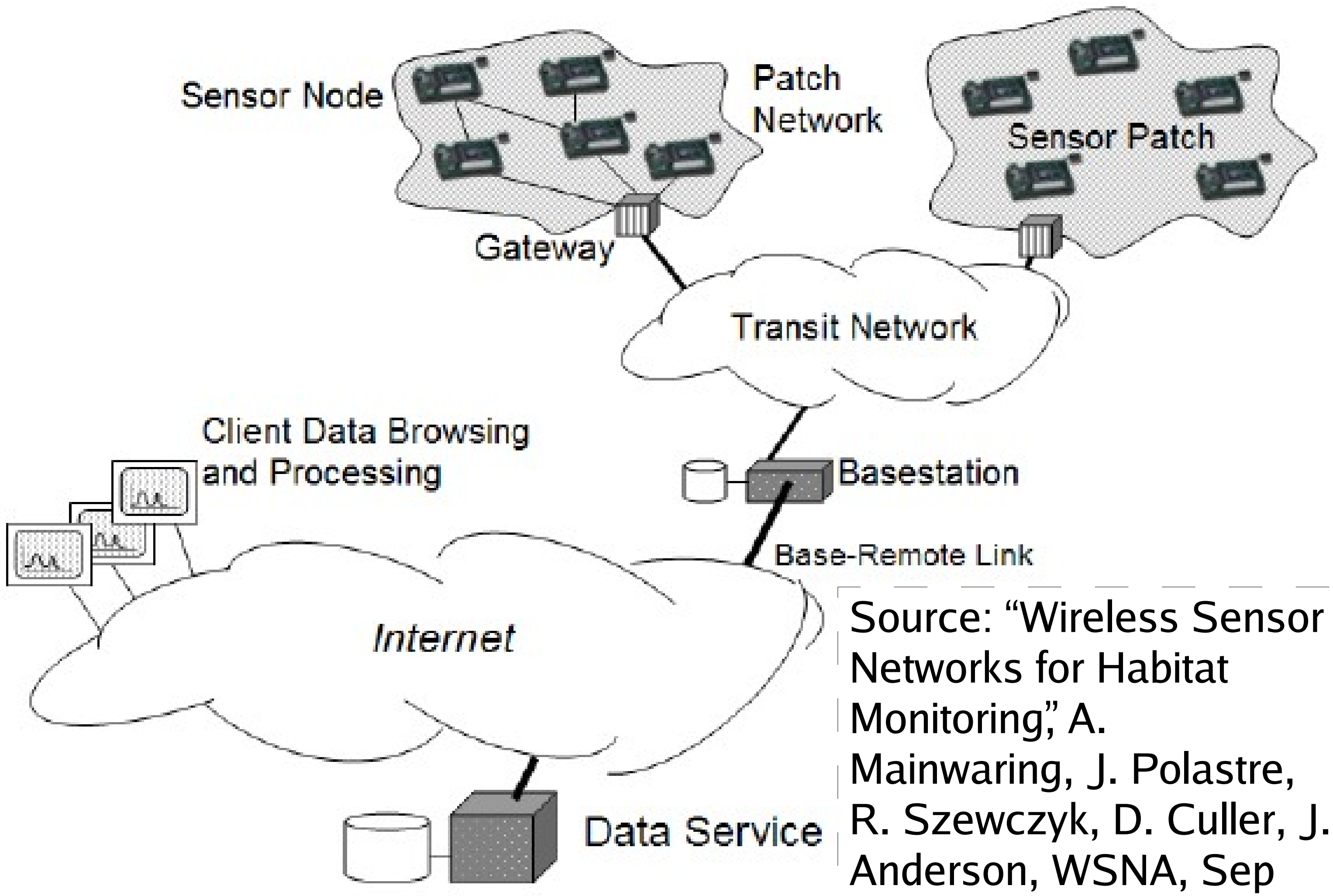
Data Acquisition Rates

- Presence/absence data: using temperature differentials
  - Every 5-10 min
- General environmental parameters:
  - Every 2-4 hours
- Popular vs unpopular sites:
  - Every 1 hour, at the beginning of the breeding season

System Goals

- Sensor network longevity: 9 months
  - Solar power where possible
  - Stable operation crucial
- Inconspicuous deployment
- Sensors: light, temperature, infrared, relative humidity, barometric pressure
- Remote data acquisition, management, and monitoring over the Internet
  - Interactive "drill-down"
  - In-situ operations also

System Architecture



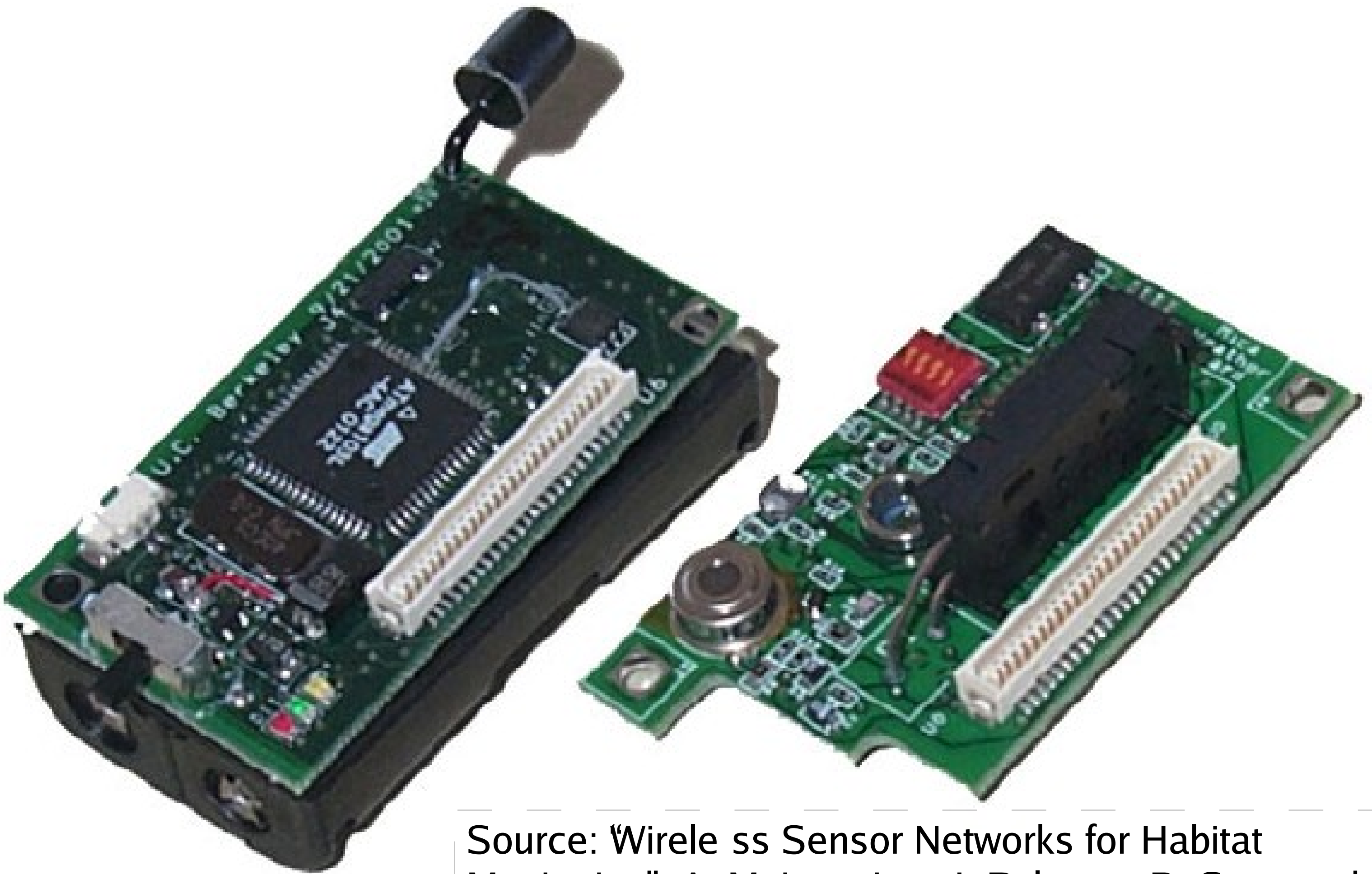
Source: "Wireless Sensor Networks for Habitat Monitoring," A. Mainwaring, J. Polastre, R. Szewczyk, D. Culler, J. Anderson, WSNA, Sep 2002

Figure 1: System architecture for habitat monitoring

Remarks on the Architecture

- Hierarchical network
- Solar panel at gateways and base-station
- In-situ retasking possible
  - Example: collect temperature beyond a certain threshold, no need for all temperature readings
- Base-station has satellite connectivity
- Base-station has RDBMS, backed up every 15-min to server at UCBerkeley

The Hardware Platform



Source: "Wirele ss Sensor Networks for Habitat Monitoring," A. Mainwaring, J. Polastre, R. Szewczyk, D. Culler, J. Anderson, WSNA, Sep 2002

Figure 2: Mica Hardware Platform: The Mica sensor node (left) with the Mica Weather Board developed for environmental monitoring applications

Features of the Platform

- Mote called Mica:
  - 4MHz Atmel Atmega 103 microcontroller
  - Single channel 916 MHz radio from RF Monolithics (40Kbps)
- Battery: pair of AA + DC boost converter
- Size: 2.0 x 1.5 x 0.5 inches
- Separate sensor board called the Mica weather board

Packaging and Deployment

Source: "Wireles s Sensor Networks for Habitat Monitoring", A. Mainwaring, J. Polastre, R. Szewczyk, D. Culler, J. Anderson, WSNA, Sep 2002

Figure 3: Acrylic enclosure used for deploying the Mica mote.

Sensor Characteristics

Sensor	Accuracy	Interchangeability	Sample Rate	Startup	Current
Photoresistor	N/A	10%	2000 Hz	10 ms	1.235 mA
I^2C Temperature	1 K	0.20 K	2 Hz	500 ms	0.150 mA
Barometric Pressure	1.5 mbar	0.5%	10 Hz	500 ms	0.010 mA
Barometric Pressure Temp	0.8 K	0.24 K	10 Hz	500 ms	0.010 mA
Humidity	2%	3%	500 Hz	500-30000 ms	0.775 mA
Thermopile	3 K	5%	2000 Hz	200 ms	0.170 mA
Thermistor	5 K	10%	2000 Hz	10 ms	0.126 mA

Table 1: Mica Weather Board: Characteristics of each sensor included on the Mica Weather Board.

Source: "Wireless Sensor Networks for Habitat Monitoring," A. Mainwaring, J. Polastre, R. Szewczyk, D. Culler, J. Anderson, WSNA, Sep 2002

Energy Budget

Total energy available: 2200 mAh
== 8.148 mAh/day x 9 months

Operation	nAh
Transmitting a packet	20.000
Receiving a packet	8.000
Radio listening for 1 millisecond	1.250
Operating sensor for 1 sample (analog)	1.080
Operating sensor for 1 sample (digital)	0.347
Reading a sample from the ADC	0.011
Flash Read Data	1.111
Flash Write/Erase Data	83.333

Source: "Wirele ss Sensor Networks for Habitat Monitoring," A. Mainwaring, J. Polastre, R. Szewczyk, D. Culler, J. Anderson, WSNA, Sep 2002

Table 2: Power required by various Mica operations.

Gateway: Design Choices

- 802.11b based
  - CerfCube platform: StrongArm-based
  - IBM micro-drive with 1GB storage
  - 2.5W power consumption
  - 12dBi omni-antenna ==> 1000 feet range
- Mote-mote connection
  - 14dBi directional antenna ==> 1200 feet range
- Packet reception rate was similar in either case, but former requires solar panel

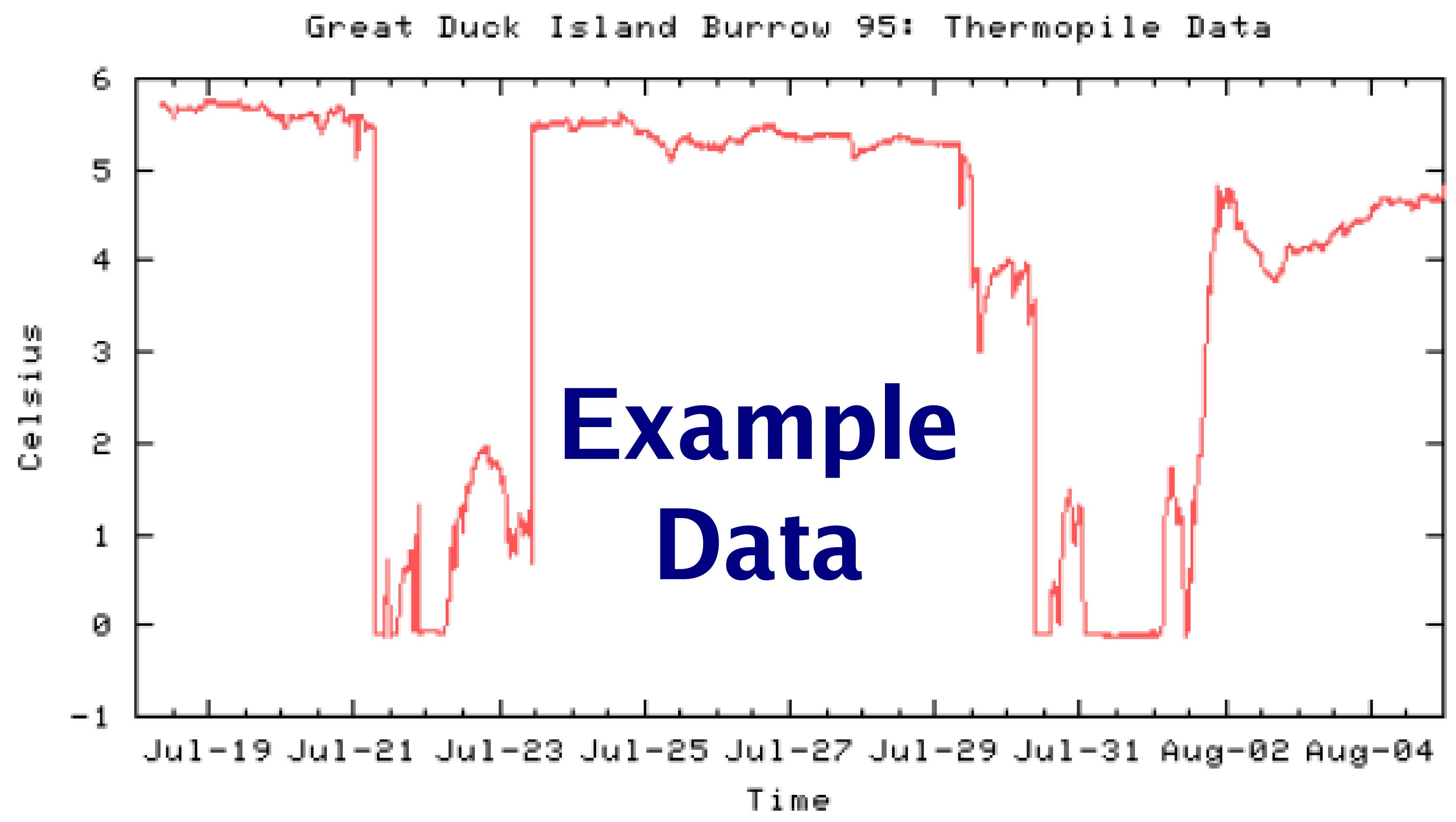


Figure 4: Thermopile data from a burrow mote on GDI during a 19-day period (July 18, 2002 to August 5, 2002).

Temperature difference due to bird (verified using recorded bird call)

Communication Protocols

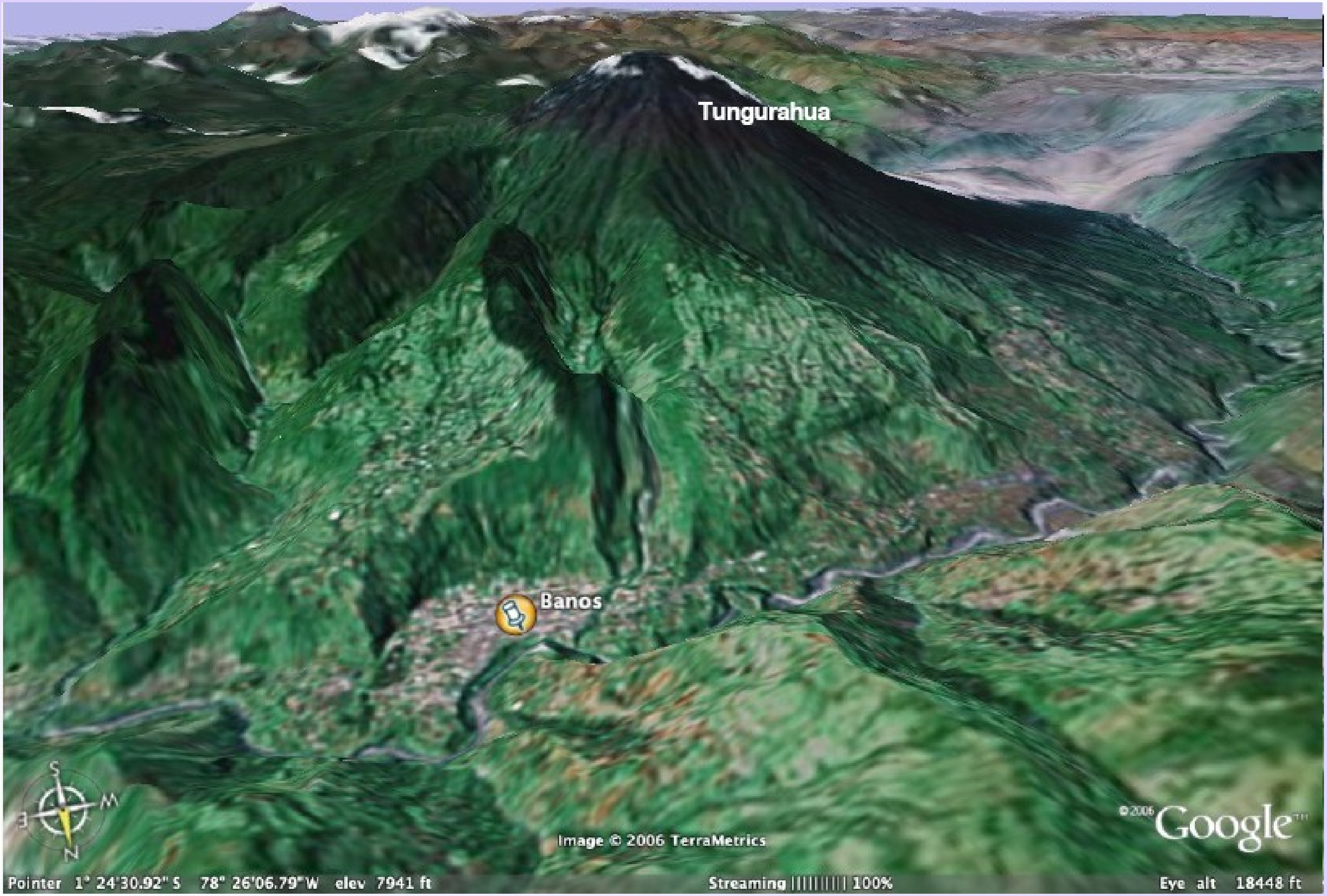
- MAC protocol, routing protocol
- Current implementation: single-hop communication to gateway
  - Periodically scheduled
- Possibilities:
  - Determine routing tree, wake up adjacent levels periodically
  - Wake up nodes along a path or subtree periodically
- Low power MAC: extend start symbol to match the wake-up frequency

Wireless Sensor Network for Volcano Monitoring

- Reference: “Dep loying a Wireless Sensor Network on an Active Volcano,” Geoffrey Werner-Allen, Konrad Lorincz, Matt Welsh, Omar Marcillo, Jeff Johnson, Mario Ruiz, Jonathan Lees, IEEE Internet Computing, Mar/Apr 2006

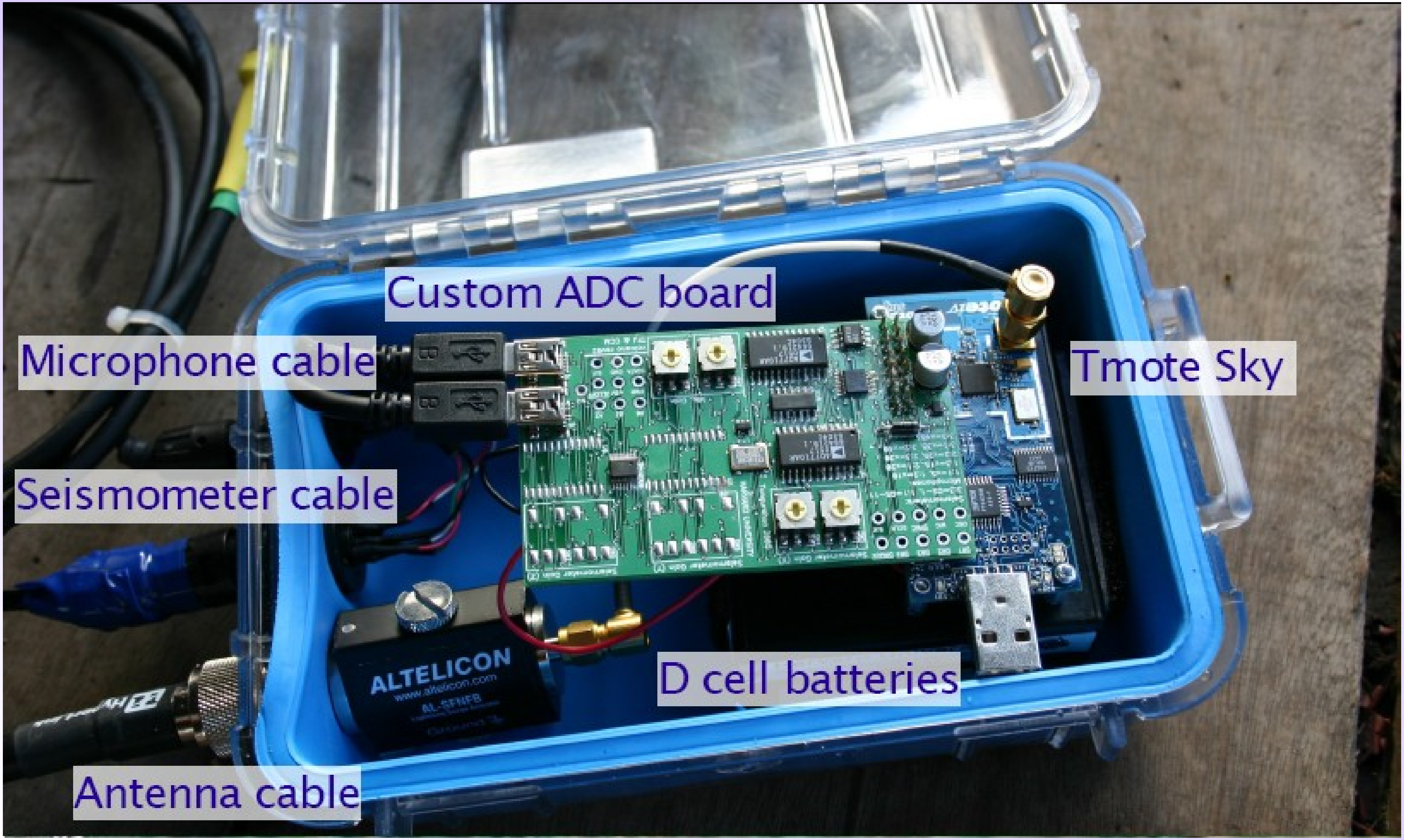
Source: “Deploying a Wireless Sensor Network on an Active Volcano,” G. Werner-Allen et. al., IEEE Internet Computing, Mar/Apr 2006

Tungurahua, Ecuador



Source: "Deploying a Wireless Sensor Network on an Active Volcano", Presentation by Matt Welsh, Harvard University

Monitoring Equipment



Source: "Deploying a Wireless Sensor Network on an Active Volcano", Presentation by Matt Welsh, Harvard University

Sensor Network Architecture

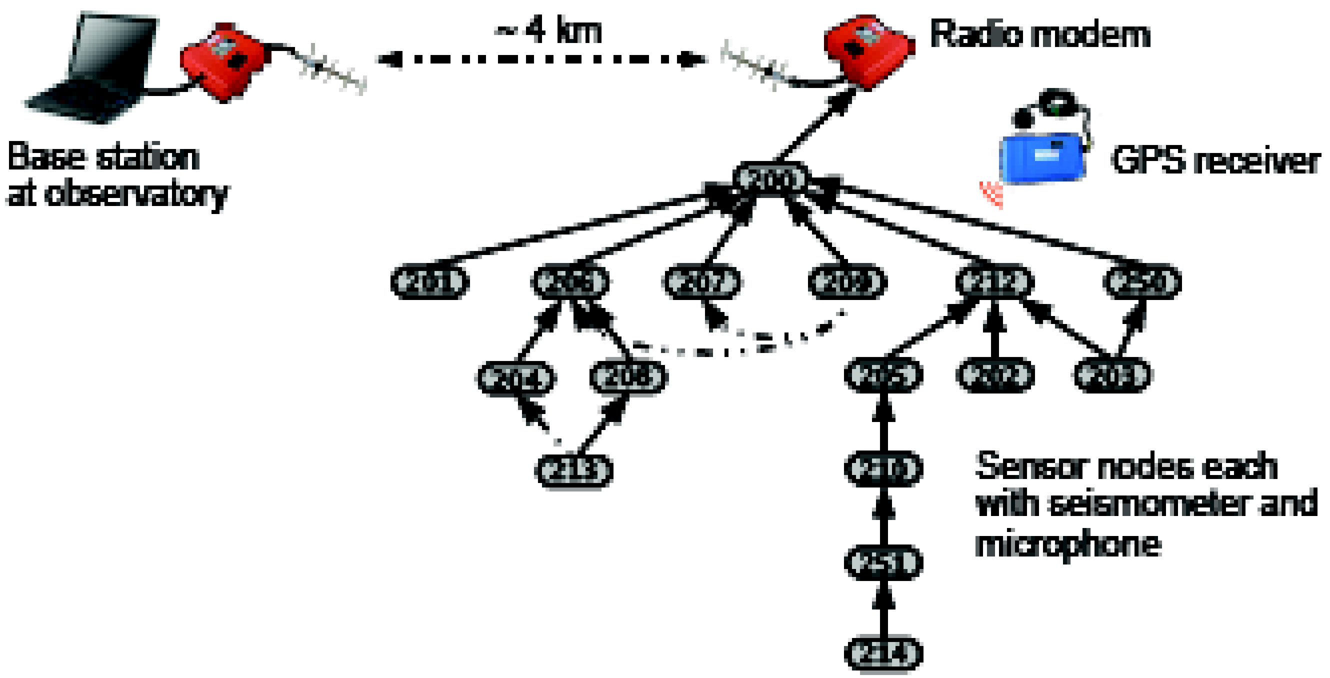


Figure 2: **Sensor network architecture.** *Nodes form a multihop routing topology, relaying data via a long-distance radio modem to the observatory. A GPS receiver is used to establish a global timebase. The network topology shown here was used during our deployment at Reventador.*

Source: “Fidelity and Yield in a Volcano Monitoring Sensor Network,” G. Werner-Allen et. al., OSDI 2006

Deployment Map

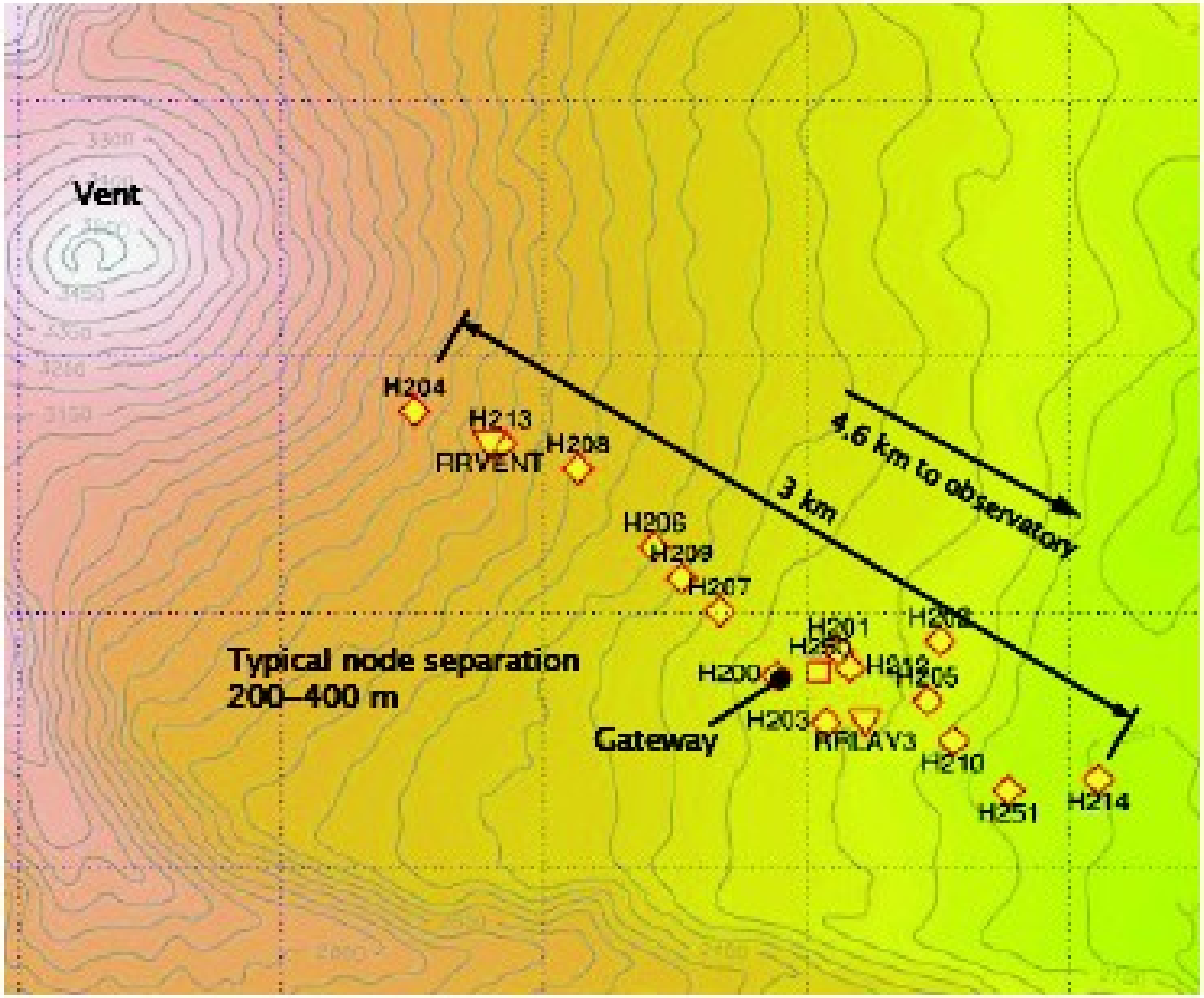


Figure 3: **Map of sensor deployment at Volcán Reventador.** *In addition to the 16 sensor nodes, two broadband seismometers with data loggers (RRVENT and RRLAV3) were colocated with the network.*

Source: "Fidelity and Yield in a Volcano Monitoring Sensor Network," G . Werner-Allen et. al., OSDI 2006

Challenges Encountered

- Event detection: when to start collecting data?
- High data rate sampling
- Spatial separation between nodes
- Data transfer performance: reliable transfer required
- Time synchronization: data has to be time-aligned for analysis by seismologists

More Applications: Industrial Monitoring

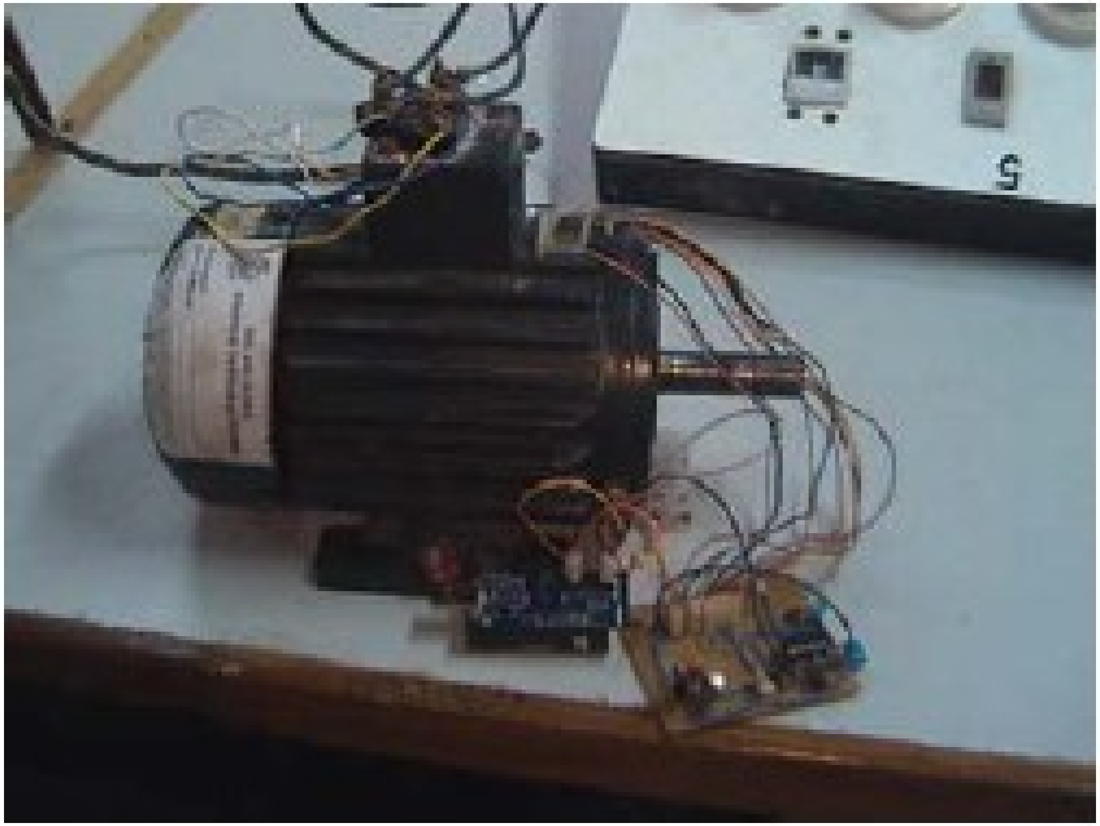
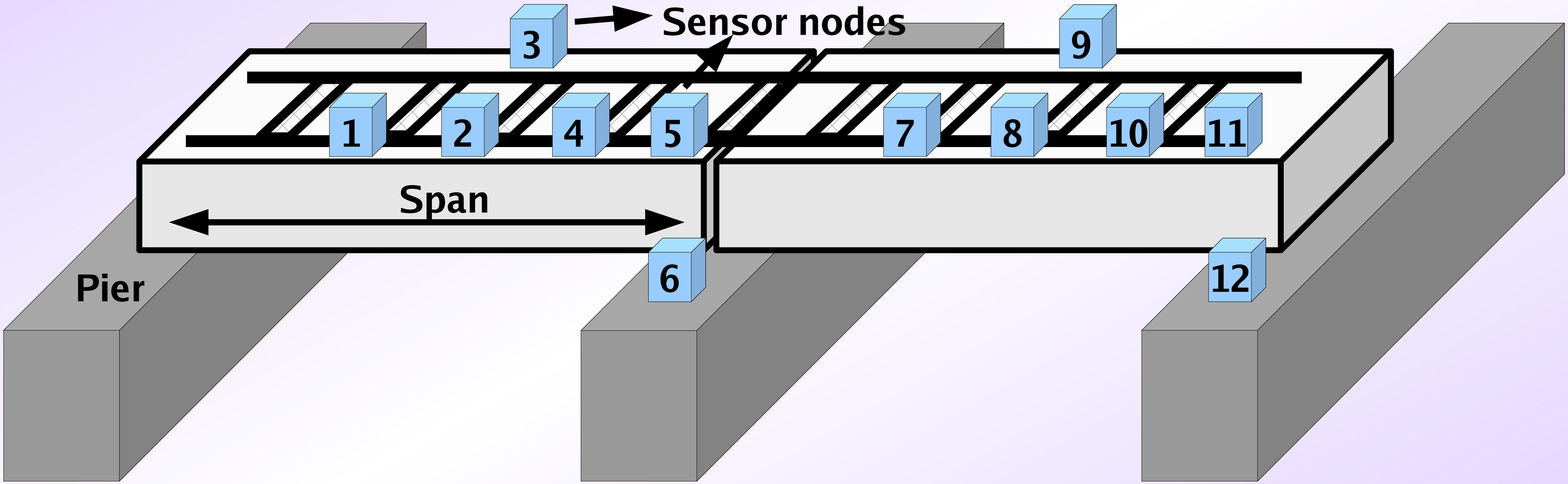


Fig. 7. Motor with sensor mounted

Source: "WiBeaM:Wireless Bearing Monitoring System," Lt Cdr VMD Jagannath, Bhaskaran Raman, WISARD 2007.

More Applications: BriMon



BriMon Field Trip (1/2)

BriMon Field Trip (2/2)